Proceedings of the American Academy of Arts and Sciences.

VOL. XLII. No. 23. — MARCH, 1907.

CONTRIBUTIONS FROM THE ZOÖLOGICAL LABORATORY OF THE MUSEUM OF COMPARATIVE ZOÖLOGY AT HARVARD COLLEGE. E. L. MARK, DIRECTOR. — No. 187.

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By E. L. Mark.

Presented December 12, 1906. Received December 17, 1906.

Any one who has had much experience in making models of microscopic objects by means of wax reconstruction-plates must have felt the disadvantages of the ordinary method of cutting out the plates with a scalpel.

Some years ago the advantages of heating the scalpel in a flame suggested to me the desirability of employing a knife heated to a constant temperature, and observation of the methods employed in making corrections to "line process" plates prepared by the so-called wax method led me to think it might be possible to use for this purpose a small gas jet attached to the knife and connected with the gas supply by a small flexible rubber tube. I did not succeed, however, in producing a device that would work satisfactorily. A little later it occurred to me that a wire heated by an electric current might be kept at a sufficiently constant temperature to answer the purpose. Accordingly in an ordinary bow-saw with large bow the saw blade was replaced by a fine wire, the ends of which were insulated from the frame and connected by means of flexible insulating wire with a 110-volt alternating electric circuit. By introducing into the circuit the proper resistance — in the form of electric lamps arranged in multiple — it was possible to heat to the proper degree the wire selected. By means of this apparatus one could melt a wax plate readily along any predetermined course, provided the wire were slowly moved back and forth as in sawing. But this apparatus was defective, owing to the lengthening of the wire and its consequent laxness when heated. It became obvious at once that for accurate work some sort of spring would have to be introduced into the mechanism to take up the slack of

the wire. But a still more serious and unexpected drawback presented itself. Unless the cutting was done very slowly, the melted wax cooled in the saw-carf behind the wire, leaving the edges of the cut almost as firmly joined as before the wire had passed through. This, together with the difficulty of holding conveniently the wax plate during the process of cutting, led to the adoption of a fundamental modification. Instead of holding the wax plate in such a position that the wire-saw could be moved freely, it seemed that a better plan would be to move the wax plate on a horizontal platform against a wire fixed in a vertical position. Some preliminary trials were made with such a device, but it soon became evident that the wire would have to be made white hot if the track through the wax plate were to be made with satisfactory rapidity. The disadvantages of this were obvious; among others, the wire became dangerously lax, and the desired rigidity could not be maintained. The remedy which at once suggested itself, and proved in the end to be practicable, was to give the wire, while keeping it taut by means of a spring, a vertical play of an inch or two, as in a jig-saw. By this means the wire surface brought in contact with the wax was multiplied many times, and a sheet of wax that quickly cooled down a *stationary* wire at the level of contact was easily melted by the moving wire.

A domestic experience in the exchange of sewing machines had acquainted me with the fact that an abandoned — but not worn out — sewing machine was worth about what it would fetch for old iron. I selected one of fairly large proportions, and proceeded to replace the needle with the electrically heated wire. It was at this juncture that the mechanical skill and experience of one of my students — Mr. J. A. Long — proved to be of great value. We together planned the details of the alterations to be made, and he executed the most of them, no professional mechanic being required at any time. The obstacle which it took us longest to overcome was the freezing of the wax in the track of the wire. I at first thought it would be necessary to use a jet of hot air to blow the melted wax away, but found on trial that a cold blast was even better, so far as getting the wax out of the saw-carf was concerned, for it left a sharper cut. After removing the presser-foot, in its place a blowpipe with a fine opening was clamped to the presser-foot bar, and so adjusted that a blast, conducted to it through rubber tubing, was directed downward on the wax plate immediately behind the electric wire. The melted wax was easily removed from the sheet, but there were two serious drawbacks to the arrangement. First, the lower end of the wire where it was attached to the lower end of the needle-bar became loaded with con-

gealed wax, which in time interfered with the working of the machine. Secondly, it was necessary to change continually the position of the wax plate, so that while being melted it should always press

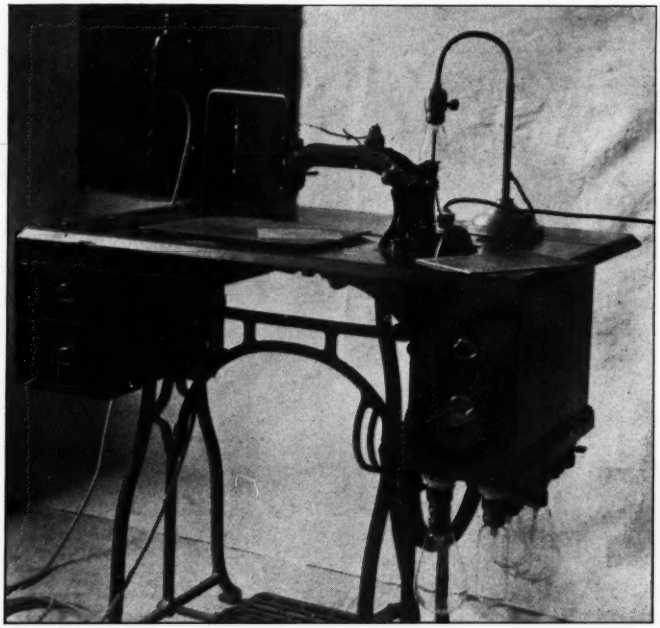

FIGURE 1 (compare Figure 3). Complete machine, showing three of the arms (the two vertical and the upper horizontal) of the "needle-bar," the two horizontal brass bars bound to one of the vertical arms by binding-screws, the short steel rod and (foreshortened) the two bars of indurated fibre supporting the spring and platinum wire. The lower horizontal arm of the needle-bar occupies a "well" which is covered by the horizontal slate platform, raised slightly above the table top. In the background are seen the Richards pump attached to a faucet and the rubber suction tubing leading to the bottle below the water tank. The electric lamps composing the rheostat are seen below the right-hand drawers of the machine.

against the near face of the wire, leaving all the melted wax on the far side of the wire. Changing the position of the blowpipe so that the blast was from below instead of from above, proved to be little, if any, improvement on the first method, for thereby the melted

wax, blown upward, fell in drops and spatters on the upper surface of the wax plate, rendering it unfit for accurate reconstruction work, and there was the same disadvantage as before, that the cutting had to be so done as to leave the saw-carf with its melted wax always on the side of the wire away from the operator. These difficulties were finally overcome by substituting suction for blast, and by causing the wire to emerge from the centre of the blowpipe hole, as will be explained directly.

As at present arranged, the apparatus consists of a sewing machine (Wheeler & Wilson), in which only a few changes have been required.

These changes consist in the removal of certain superfluous parts, such as the presser-foot, the bobbin and bobbin-holder, etc., and the substitution for the needle and needle-bar of an arrangement for holding the heated wire.

The needle-bar is replaced by a cylindrical steel bar of precisely the same diameter as the original needle-bar. This new bar may for convenience be called "needle-bar" (B, B, Figure 3). It is thrice bent at right angles, thus giving four regions, or arms, — two vertical and two horizontal. The first of the two vertical arms is inserted, in place of the original needle-bar, into the bearings of the head (H), and fastened by a binding-screw to a block which in turn is connected to the lever (V) by means of the link (L). The upper horizontal arm of the bar is made about as long (20 cm.) as half the diameter of the largest wax plate which it is designed to cut. The bending is such that this arm and the two vertical arms are in one plane; the fourth (lower horizontal) arm is bent out of that plane, its free end being nearer the operator than the corresponding end of the upper horizontal arm. A vertical slit in the free end of the lower arm receives a copper wire, which is held firmly by a binding-screw and terminates in a hook, as seen in Figure 3. The lower end of the electrically heated wire (W), which is platinum, is made into a loop that can be slipped on to this hook. The loop at the upper end of the platinum wire is likewise made to slip on to a hook at the lower end of a brass wire, which is supported indirectly by the first vertical arm of the bent steel rod, or "needle-bar." A part of the brass wire is bent into a spiral spring (S), which serves to keep taut the heated wire (W), the lower end of the brass wire being free to move up and down through a hole in the lower of the two short horizontal square bars of indurated fibre which support it. These two bars are clamped by binding-screws to a short vertical steel rod, which is in turn attached to the first vertical arm of the "needle-bar" by means of two square rods of brass, bored at each end to receive the steel rods, and furnished with set-screws. The whole of the apparatus thus far de-

scribed will evidently be moved up and down with the oscillating vertical motion of the lever V, and is represented in Figure 3 at about the middle point of its excursion, which in this machine amounts

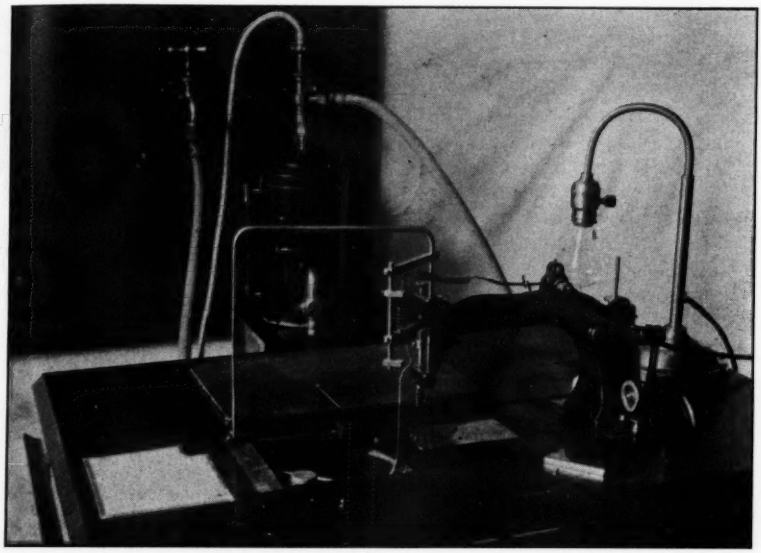

FIGURE 2. The top of the machine seen obliquely from above. The slate platform, showing a central hole for the nozzle of the copper tube and a slot running from it to the front margin of the platform, has been pushed back so as to uncover the "well," in which are seen the round screw cap of the hot-water tank, and immediately beyond it a portion of the lower horizontal arm of the "needle-bar." In addition are seen the two levers (a, b) which are used in raising the far edge of the platform. At the left of the "well" is the removable felt screen, and in the background the Wagner und Muntz pump. The platinum wire (which has been purposely made more conspicuous than it really is) is shown with the supporting brass wire and spring, and likewise the manner in which the latter are supported by passing through the bars of indurated fibre. The portable lamp is seen at the right.

to 35 mm. Supporting the upper wire and spring by two sets of horizontal bars bored to receive the cylindrical rods has the advantage of allowing one to adjust the upper hook vertically over the lower hook with great ease and accuracy. Once clamped in the proper position, these bars need no resetting. The use of indurated fibre, which is a

poor conductor, for the shorter horizontal bars, serves to insulate, as well as to support and guide, the upper wire and spring. To prevent lateral vibration of the long, or second, vertical arm of the "needle-bar," a bearing is provided at the level of the table top of the machine, as shown in Figure 2.

The electric circuit used to heat the wire W is established by clamping the wire of one pole to the head (Figure 3, H) by a binding-screw (seen directly below the axle of the lever), and connecting the other with the upper end of the insulated brass wire and spring. Thus, head, lever, and bent "needle-bar" form a part of the circuit. In this circuit is introduced a rheostat (R, Figure 3) consisting of some eight or nine electric lamps of candle-power varying from 4 to 50, arranged in multiple, each with separate key. These are seen in Figure 1, beneath the drawers at the right of the figure. A portable lamp on the table (shown in Figures 1 and 2) is constantly in the circuit, and serves to illuminate the wax plate while cutting. With an alternating current of 110 volts the candle-power required properly to heat the wire (W) — a platinum wire of 26 standard gauge (about 0.4 mm. in diameter) — is between 50 and 100. The rheostat described allows one to adjust the resistance to any voltage ordinarily used in electric lighting.

The removal of the melted wax is effected by suction produced by using a Bunsen pump. Figure 1 shows the machine set up with a pump of the Richards pattern ; Figure 2, with a more efficient special pump, made by Wagner und Muntz, Munich. With a pressure of 30 or 35 pounds either pump will effectually withdraw the melted wax. To succeed with this suction apparatus, which is an essential part of the outfit, requires careful attention to certain conditions. The sucking tube must be hot enough to keep the melted wax from immediately hardening, and it must be very close to the under surface of the wax plate at the point where the plate is being cut. The manner in which this has been accomplished is shown in Figure 3. A quarter-inch (6 mm.) copper tube passes through a water reservoir heated with an alcohol lamp, shown indistinctly in Figure 1. The lower end of the copper tube ends in a glass bottle with an air-tight rubber stopper pierced by a bent glass tube (D, Figure 3), to which the suction tube from the pump (Figure 1) is attached. The tube O is for the escape of steam from the water tank. The upper end of the copper tube is drawn out into a bent nozzle (N, Figure 3, seen in vertical and in horizontal section), with a narrow (about 2 mm.) orifice. In the convex side of the terminal bend is cut a longitudinal slot (T), which is slightly wider than the diameter of the platinum wire. The wire, without being detached from its hooks, is slipped into the slot so as to occupy the centre

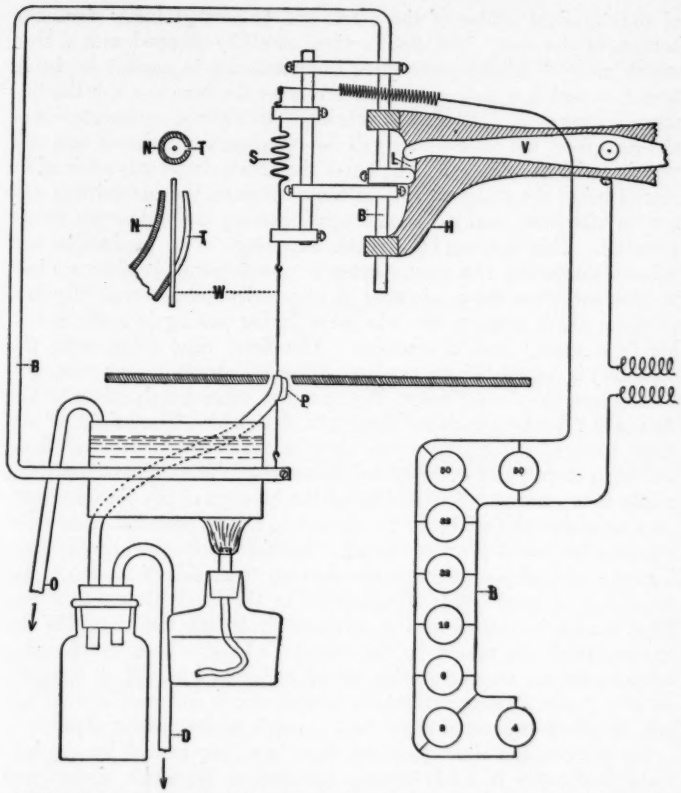

FIGURE 3. Diagrammatic representation of the essential parts of the apparatus. These are all shown in vertical section, except the rheostat, which is shown in horizontal projection. Near the middle of the rectangular area, bounded by the arms of the "needle-bar" (B, B) are shown in vertical section the nozzle (N) with its slot (T) and the platinum wire (W); and immediately above this a horizontal section of the same at the level of the letter N of the vertical section.

B, B. The two vertical arms of the "needle-bar"; D, glass tube terminating in the bottle, which also receives the copper tube; the rubber suction tube is attached to the glass tube at D; H, portion of the "head" of the sewing machine, which receives the "needle-bar"; L, link by which the "needle-bar" is attached to the lever; N, nozzle of the copper tube; O, orifice of tube for the escape of steam from the hot-water tank; P, metal plug to fill the slot in N; R, rheostat; S, brass spring to keep the platinum wire taut when hot; T, slot in one side of copper nozzle; V, lever connected with crank wheel; W, platinum wire.

of the terminal orifice of the nozzle and to emerge below from the bottom of the slot. The slot is then carefully stopped with a thin metal plug P (slight projections from its surface prevent its being forced inward too far), so that air can enter the tube through the terminal orifice only. If this orifice is kept close to the under surface of the wax plate, the melted wax will be completely withdrawn and will run down into the glass bottle; but if the orifice drops only a few millimetres below the under surface of the wax plate, the melted wax will not be withdrawn and will soon congeal, leaving the cut edges firmly reunited. This fact has been taken advantage of to produce at will either a temporary or a permanent cut. As it would be inconvenient to raise and lower the nozzle with its attached water reservoir, the slate platform which supports the wax plate during cutting is made movable in a nearly vertical direction. The front edge (that next the operator) is supported on two round-headed screws, — one seen distinctly near the dotted line a, Figure 2, the other faintly, close to the detached "front plate-slide," further to the right. The height of the front edge of the platform can thus be regulated by turning these screws in or out, and accurate adjustment to the height of the fixed nozzle thus secured. The middle of the far edge of the platform rests on a square block (a, Figure 2) screwed to a long horizontal arm turning on a horizontal pivot at the left. Another horizontal arm (b) turning on a vertical pivot engages the slanting under side of the block, and when moved in a certain direction raises the block some 6 or 8 mm. This second horizontal arm is actuated by levers, not shown in the figures, which are moved by the operator's knee. Thus the far edge of the platform may be quickly raised or lowered at will, so that the middle of the platform, where the heated wire is melting the wax, will also be raised or lowered about half as much as the distant edge.

To prevent the slate platform from becoming heated by the hot-water tank below it, a felt lining is attached to its under surface and a removable screen of the same material is placed over the tank. This is seen at the left in Figure 2 — a square sheet with a square notch cut out of one corner to accommodate the platform-block.

As thus arranged, the wire may be readily heated to the desired temperature, and, by operating the pedal as in sewing, it may be made to make rapid vertical excursions. Since the wire is central to the orifice in the copper tube, the wax plate may be moved in any direction, the melted wax being withdrawn with equal facility, whatever the direction of the cutting. The fine sharp cut, exactly perpendicular to the plane of the wax, which is produced by this machine, seems to meet all the requirements for cutting wax plates rapidly and accurately.